Rehabilitation of A Mined Area in Himalayas by Geojute and Other Measures

G. P. Juyal, G. Sastry & M. S. Rama Mohan Rao
Central Soil & Water Conservation Research & Training Institute, Dehradun, India

ABSTRACT: Mining in the Himalayan hills in India has resulted in severe soil erosion, 550 ton/ha. A limestone mined watershed, 64 ha, was selected and treated with soil and water conservation measures for slope protection and channel stabilization. Geojute and synthetic geotextiles were used for establishment of vegetation on degraded and steep mine spoil slopes. Geojute showed better performance in establishment of a vegetative cover as compared to synthetic geotextiles. The cost of Geojute could be further reduced by suitably modifying the mesh opening ratio. Conservation measures coupled with geojute, reduced soil erosion to 8 t/ha, near permissible limits and water, plant and soil resources improved.

1 INTRODUCTION

The Himalayan hills, covering an area of about 0.5 million sq km in India, contain a large variety of minerals, including limestone, the one being used by industries like steel, sugar, cement, textiles etc. The lime stone is exploited through open cast mining, spread over an area of about 1400 ha in Mussoorie hills of Doon Valley, resulting in high erosion rates, 550 ton/ha/yr (Katiyar *et al.*, 1987), as compared to 270 ton/ha from similar areas in USA (Tank, 1973).

Apart from land degradation, heavy soil erosion rates resulted in disruption to communication systems, destroyal of eco-system and higher sediment loads to rivers and reservoir systems. The damages are not restricted to the mined sites alone, but are manifested extensively over a wide area on the downstream. Land degradation due to mining in Doon Valley, for example, reduced food production by 28%, water resources by 50% and livestock production by 35% (Anonymous, 1988). A limestone quarry area was selected in 1984 for development of appropriate soil conservation technology on watershed basis to determine the effectiveness on erosion control, watershed hydrology and restoration of eco-system.

2 DESCRIPTION OF EXPERIMENTAL WATERSHED

Sahastradhara lime stone quarry watershed, area - 64 ha, is situated in the lesser Himalayan zone of Doon Valley at an altitude from 820 m - 1310 m above m.s.l. (Fig.1).

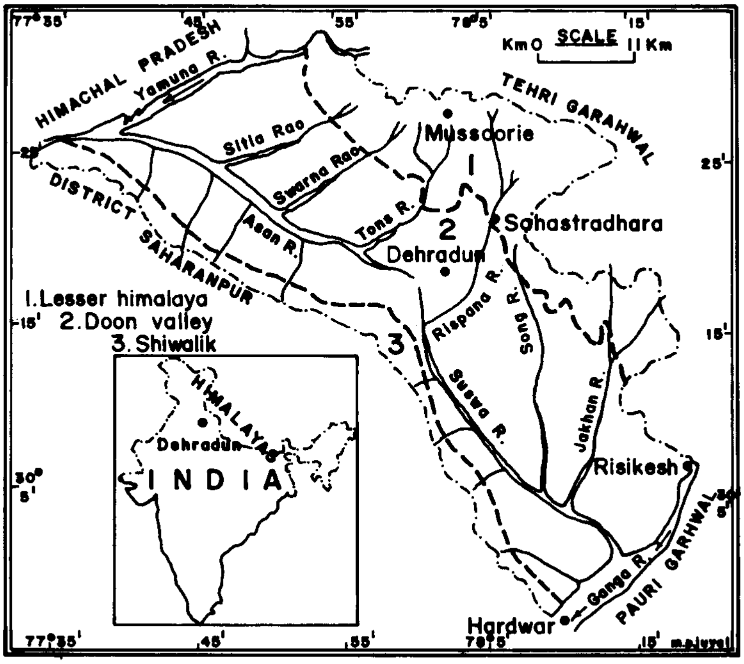

Fig 1 Location of experimental watershed

The area receives an annual rainfall of about 3000 mm, 80% of which is received during monsoon months of June to September. The area is characterized with weak geology of Krol belt comprising limestone, gypsum, marble, slates and dolomite, etc. The minespoil is sandy loam in texture with high gravel content (60% of the material is greater than 16 mm size), alkaline(pH-8.1), calcareous($CaCO_3$-55%) and poor in fertility status (Organic carbon - 0.13%, Nitrogen - 0.02% and available P_2O_5-5.4 kg/ha) with high infiltration rate(30 cm/hr) and poor water holding capacity. The poor fertility of the mine spoil inhibits the growth of vegetation. The watershed is having an average slope of 50%, at some points the slopes are exceeding over 100%.

The unscientific mining operations destroyed almost all the vegetative cover of the area comprising mixed deciduous forest species of sub tropical type. This along with high rainfall and steep slopes caused heavy debris movement from the watershed, leading to frequent vehicular disruption, entailing a huge recurring maintenance cost of Rs 0.1 million annually. The siltation of the river downstream led to frequent floods in monsoon destroying agricultural and other forest lands.

3 TREATMENT MEASURES

Based on the topographical, vegetative and soil surveys, a corrective plan consisting of a combination of engineering and vegetative measures was implemented. The critically eroded areas for stabilization in the mined watershed were identified as (a) unstable minespoil slopes and (b) drainage channels. Engineering measures were first implemented to provide stability to the slopes and check the excessive runoff and debris flow. Mild slopes (< 30%) were stabilized by digging contour trenches (0.3 m X 0.3 m) at a vertical interval of about 1.0 m and planted with suitable vegetative species. Steep slopes were vegetated with the application of Geojute geotextile. The steep landslide affected slopes were stabilized with logwood crib structures. Small gullies and channels were treated with loose stone/brushwood check dams. The main drainage channels, transporting the bulk of debris load, required the most intensive treatment. Gabion (stone filled wire meshes) check dams/cross barriers and silt detention basins across the channel width (6 m - 15 m) were constructed to reduce channel slope and thereby reduce the transportability of the flow within non-erosive limits, and retain the debris within the watershed. A series of such structures (230 nos.) were constructed along the channel length of about 1500 m. Spurs (16 nos.) and toe walls (150 m) were constructed in the lower reach of channels to guide the flow and prevent bank erosion.

Quick growing and hardy species such as *Acacia catechu*, *Leucaena leucocephala*, *Salix tetrasperma* (trees), *Vitex negundo*, *Ipomoea carnea* (Shrubs) and grasses such as *Crysopogon fulvus*, *Eulaliopsis binata*, *Saccharum* spp., having fuel, fodder and fiber value were planted in the area. Seeding/planting was done in contour trenches/pits filled with good soil mixed with local minespoil, wherever needed.

4 GEOJUTE FOR SLOPE STABILIZATION

Mineral rejects and overburden piled up at places in the watershed were highly erodible and difficult to vegetate. Geojute (jute fibre woven in open mesh) was tried to give temporary protection to these slopes and help protect the vegetation till it establishes. The specifications of the geojute used were : grade - 500 g/sqm, strand thickness - 5mm and open area - 65 percent. Different slopes (30-70%), covering an area of 0.86 ha were tried. Besides Geojute, synthetic geotextiles like Netlon (CE-131) and Geocell were also experimented for their performance.

4.1 Application technique

Seeds of suitable tree species (*Acacia catechu*, *Leucaena*) were spread on the area and scarified. Grass mulch locally available was spread @ 2-3 ton/ha. Geojute was spread on the area loosely. The two adjoining widths were overlapped by about 10 cm and fastened with jute threads. Wooden sticks were driven to hold the mesh at place. Rooted slips of grasses like *Saccharum spontaneum* and *Thysanolaena maxima* (broom grass) and cuttings of *Ipomoea carnea*, *Vitex negundo*, *Arundo donax* and Hybrid Napier were planted in openings between geojute strands at close spacings.

4.2 Vegetation establishment

In the geojute area there was good establishment of grasses compared to control. *Thysanolaena maxima* grass recorded an yield of 3052 kg/ha (oven dry) compared to 640 kg/ha in control after 3 years of plantation. Hybrid Napier when planted in contour trenches filled with good soil mixed with farm yard manure (FYM) recorded an excellent yield of 9850 kg/ha compared to 1960 kg/ha in control.

Saccharum spontaneum also showed good performance. The grass roots provided good anchorage to the soil in the second year of plantation itself. Survival of tree species was observed to be poor. The Geojute biodegraded in less than three years, by then the vegetation established itself. The vegetation establishment in the synthetic geotextiles (Netlon and Geocell) was poor compared to Geojute. This might be due to the adverse micro-climate created by the local heating of the synthetic material.

4.3 Application cost

The cost of geojute application was Rs.8.00 per sqm, comprising of cost of geojute, labour and plantation material (Juyal *et al.*, 1991). The rates varied from $ 1.50 - 3.90 per sqm in USA in similar situations (Goldman *et al.*, 1986). The cost of geojute application can be reduced by suitably designing the mesh opening ratio. The cost of synthetic geotextiles was Rs 110 per sqm and was not an economically viable proposition for soil conservation programmes.

5 ENVIRONMENTAL IMPACT OF CONSERVATION MEASURES

The watershed was monitored for the environmental and hydrological impact of conservation measures. Raingauging station comprising of an automatic and standard raingauge and runoff gauging station consisting of trapezoidal flume with stage level recorder were established for hydrological monitoring.

5.1 Erosion Control

The soil and water conservation measures have reduced the monsoon runoff from 57% to 37%, delayed and attenuated the flood peaks by 20 minutes and more than 60% respectively, thereby reducing the soil erosion to 8 ton/ha, near permissible limits within a period of 6 years. This was achieved through protective vegetative cover on the slopes and channel slope reduction from 38 to 20% due to construction of engineering structures. In addition the structures retained a huge quantity of debris (62,000 cu m) which would have otherwise moved down the watershed causing road blockage and other damages.

5.2 Water resource improvement

With more infiltration of runoff water into the soil profile by the conservation measures, base flow increased during dry weather period (October - May) and new water sources/ springs regenerated in the watershed. The dry weather flow measured in the months of November and February was 265 and 100 cum per day respectively, augmenting the water availability for domestic and irrigation purposes.

The water quality also improved as a result of treatment measures bringing down the concentration of suspended sediment (2.36 to 0.57 g/100 cc). The toxic amounts of calcium, magnesium and sulphates were brought down to approved standards of potable water, Table 1 (Juyal *et al.*, 1993).

Table 1 Improvement in water quality (ppm) by treatment measures.

Description	Ca	Mg	SO_4
Untreated mine	389	120	756
Treated mine	74	34	138
Standards	75	50	250

5.3 Soil improvement

The soil properties in the watershed also improved as a result of conservation measures. Organic carbon increased from 0.13 to 0.26% and available P_2O_5 increased from 5.4 to 32 kg/ha whereas $CaCo_3$ decreased from 55 to 34% and pH reduced from 8.1 to 7.7 over a period of 7 years.

6 CONCLUSIONS

With appropriate soil and water conservation technology, the mined areas can be rehabilitated and plant and water resources regenerated. Geojute is recommended for establishment of grasses and shrubs on unstable degraded slopes. Owing to high cost and poor vegetation establishment, synthetic geotextiles are not recommended. Research efforts are, however, needed to reduce cost of Geojute application by evolving an optimum mesh opening ratio.

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